CHAPTER 11

MODEL STUDIES

11-1. General. Hydraulic model investigations are an invaluable tool in the final design of breakwaters and jetties. Design guidance presented herein is sufficient for selection of structure type and preliminary design; however, proposed final designs may be optimized or at least check-tested in a hydraulic model study. The decision to conduct a model study should be based on an evaluation of such factors as complexity of bathymetry and structure geometry, estimated project costs, and consequences of failure. Experience has shown that site-specific model studies generally yield an excellent return on their original investment, either through savings in original construction costs as a result of optimization, or savings in repair and/or replacement costs as a result of identifying unsatisfactory designs prior to their construction.

11-2. Purpose of Model Tests. Hydraulic model tests of breakwater and jetties generally are conducted to

a. Determine minimum stable armor weights for rubble-mound structures.

b. Optimize the armor slopes and crown elevation of rubble-mound structures.

c. Quantify wave heights on the harbor-side of rubble-mound structures created by overtopping and transmission through the structure.

d. Determine wave transmission characteristics of floating breakwaters.

e. Measure mooring forces exerted by floating breakwaters.

11-3. Field Data Required.

a. In the design of hydraulic models, it is important that adequate information is available about the site so that major problems confronting the field design engineer are clearly understood by the laboratory engineer. The purpose and scope of model studies should be determined to the fullest extent possible at the outset. Model design and the testing program then can be better directed toward solution of those parts of the overall problem that are the most critical and are best suited for investigation by a hydraulic model. In addition to general information about the design problems (to determine the purpose and scope of the model investigation), the design, construction, and operation of models of coastal structures exposed to wave action require (1) detailed information on the geometry of the structure and materials of which the structure will be composed, (2) information concerning the bottom aterials upon which the structure will be situated, (3) the bottom contours along the alignment of the structure and seaward of the structure to a water

depth of nearly one-half the maximum wavelength, and (4) statistical data to determine the frequency of occurrence of waves with different heights and periods at the structure site.

b. The normal water depths at the structure site and the range of water surface elevations about the selected still-water level are important variables in the design of coastal structures, selection of design waves, and selection of model test conditions. Thus, statistical data of tidal ranges, wind setup, or storm surge are necessary for the design and efficient operation of models for all types of coastal structures.

11-4. Selection of Model Scale. During the planning and design phases of a hydraulic model study of breakwaters or jetties, the model scale must be determined. Scale selection normally is based on the following factors:

a. Preclusion of stability scale effects.

b. Size of model armor units available compared with the estimated size of prototype armor units required for stability.

c. Depth of water at the structure.

d. Capabilities of the available wave tank and wave generator.

Depending on the size of structure and wave conditions being represented, typical values of the model scale or length ratio (L_r) range from 1:25 to 1:50. Thus, models are typically from 25 to 50 times smaller than their prototype counterparts.

11-5. Model Laws. Following selection of the linear scale, the model is designed and operated in accordance with Froude's model law (item 121). Scale relations used for design and operation are given in the following tabulation:

Characteristic	Dimension[(a)]	Scale Relation[(b)]
Length	L	L_r
Area	L^2	$A_r = L_r^2$
Volume	L^3	$V_r = L_r^3$
Time	T	$T_r = L_r^{1/2}$
Force	F	$F_r = L_r^3$

(a) Dimensions are in terms of force (F), length (L), and time (T).

(b) The subscript r means "ratio."

11-6. Wave Generators. Model waves are normally generated by vertical-motion, plunger-type wave generators, horizontal-motion, piston-type wave generators; hinged-motion, flapper-type wave generators; or some combination of these. In each case, the movement of the wave board causes a displacement of water incident to its motion, which can be monochromatic or spectral.

11-7. Bottom Slope. Proposed breakwaters and jetties are normally fronted by variable bottom slopes. Effects of the bottom slope are important if the structure will be exposed to depth-limited breaking wave attack, since the height of depth-limited breaking waves increases as the slope becomes steeper. Therefore, the steepest slope fronting the structure is usually chosen for representation in the model.

11-8. Method of Constructing Test Sections. Model breakwater and jetty sections are constructed to reproduce as closely as possible results obtainable by a general coastal contractor. Core material, dampened as it is dumped by bucket or shovel into the flume, is compacted with hand trowels to simulate natural consolidation resulting from wave action during construction of the prototype structure. Once the core material is in place, it is sprayed with a low-velocity water hose to ensure adequate compaction of the material. Underlayer stone is then added by shovel and smoothed to grade by hand or with trowels but it is not packed in place. Armor units used in the cover layer are placed by hand, usually in a random manner; i.e., laid down in such a way that no intentional interlocking of the units is obtained. Model elevations can be controlled with an engineer's level to a tolerance of $\pm$ 0.005 foot.

11-9. Still Water Levels. Still water levels (swl's) for breakwater and jetty models are selected so that the various wave-induced effects that are dependent on water depth are accurately reproduced. These effects include armor stability, amount of wave overtopping, and wave energy transmission through the structure. Generally, a range of swl's will be investigated.

11-10. Wave Characteristics. In planning the testing program for model investigation of wave-action problems, it is necessary to select wave dimensions that will allow a realistic test of the proposed structure. Wave transmission and overtopping tests are conducted for a range of wave conditions, thereby allowing determination of the structure's effectiveness as a function of wave height and period. Stability of the structure is investigated for the most severe wave conditions expected to occur during its design life.